

PipeLine Underground Trenchless Overhaul (PLUTO)

PI: Todd Danko, GE Research

Team Members: Warren Environmental, Garver



GE Research



WARREN
ENVIRONMENTAL



Project Vision

Improve pipeline longevity and maintenance efficiency by developing a minimally invasive, long-range, structural pipeline rehabilitation system

Total Project Cost:	\$7.1M
Length	36 mo.

Project Objectives & The Concept

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Project Goals

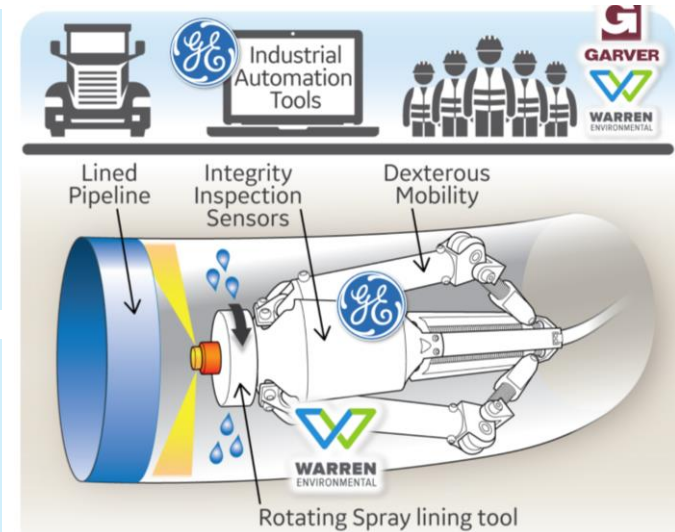
- **Minimally Invasive Structural Pipeline Rehabilitation:** Apply structurally independent liner to leaking cast iron and steel pipelines, reducing gas pipeline transmission loss and improving operational reliability
- **Economical Infrastructure Maintenance:** Rehabilitate existing pipe infrastructure through sparse access points rather than replacement through continuous pipeline excavations → ½ to 1/20th of the cost of full pipe replacement

High-Level Approach

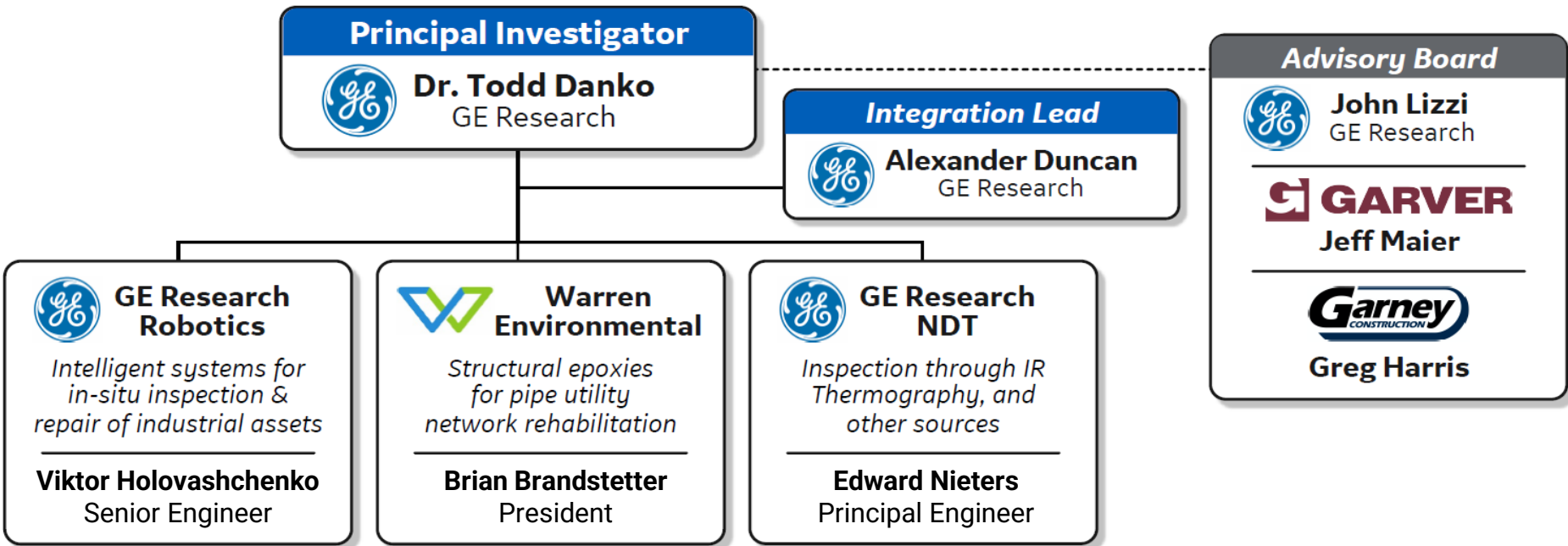
- **Access:** Dexterous pipe crawler system with tether managing features for scalable range extension
- **Prepare:** Selective surface preparation for high-speed deployment, and structural liner independence from host with intimate bonding to service connections, terminations and other critical points
- **Material and Process:** Water, wastewater and fuel sector-proven epoxy for long-life, structurally independent pipe linings
- **Inspect:** Advanced inspection technologies paired with deep learning analytics for detecting life limiting defects

Technology Impact

- **Long-Range:** Up to 1000 m one-way travel, minimizing excavations & reducing interruptions
- **Fast:** 1000 m pipeline inspection coating and validation ~36 hours
- **Longevity:** 75+ year service life that is as good or better than new pipe installation

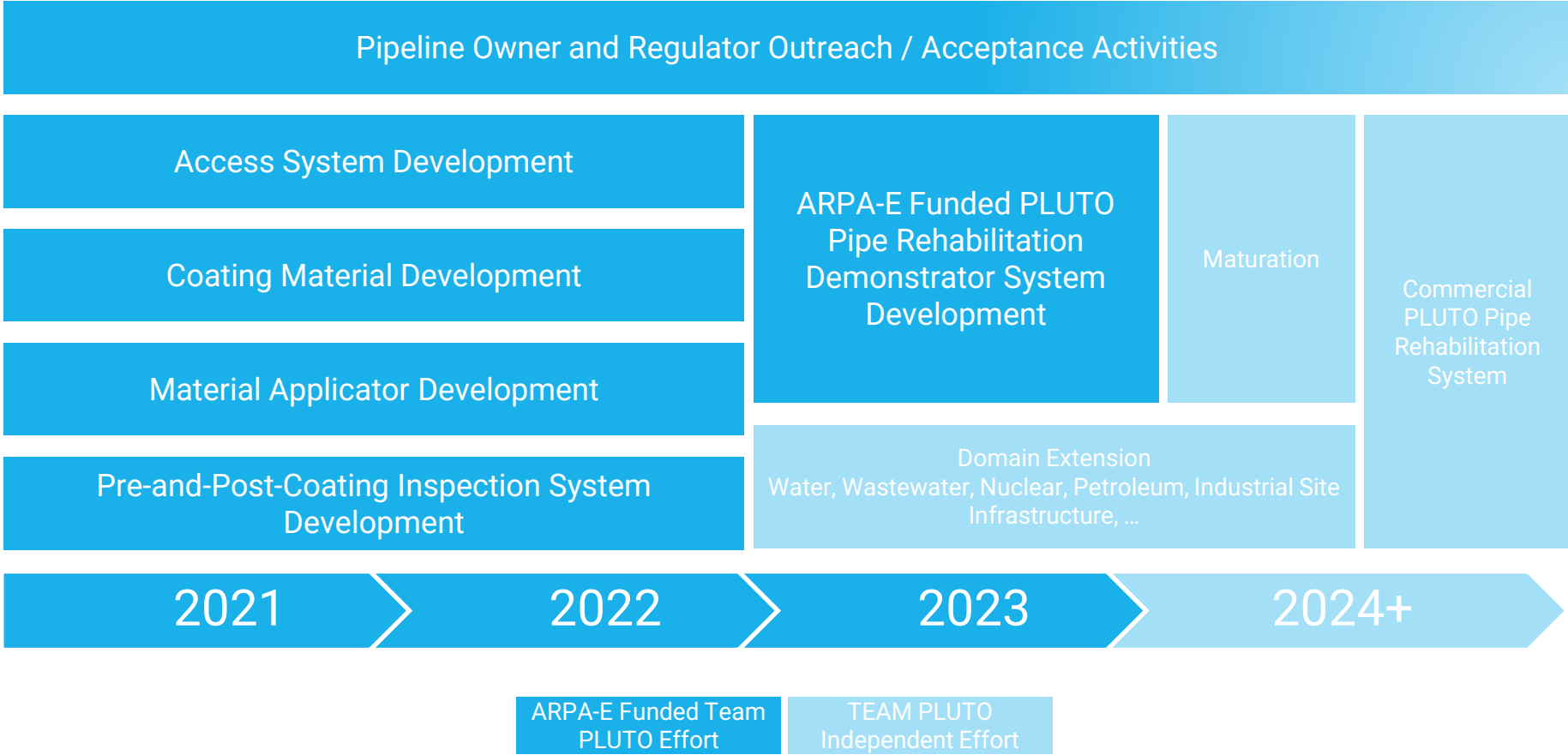


The Team – org chart



Project Timeline

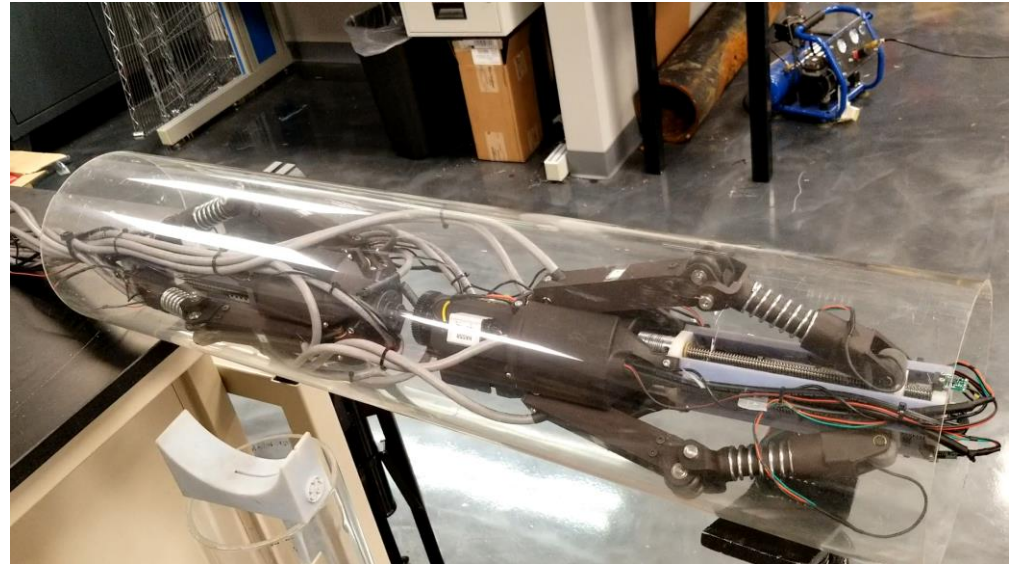
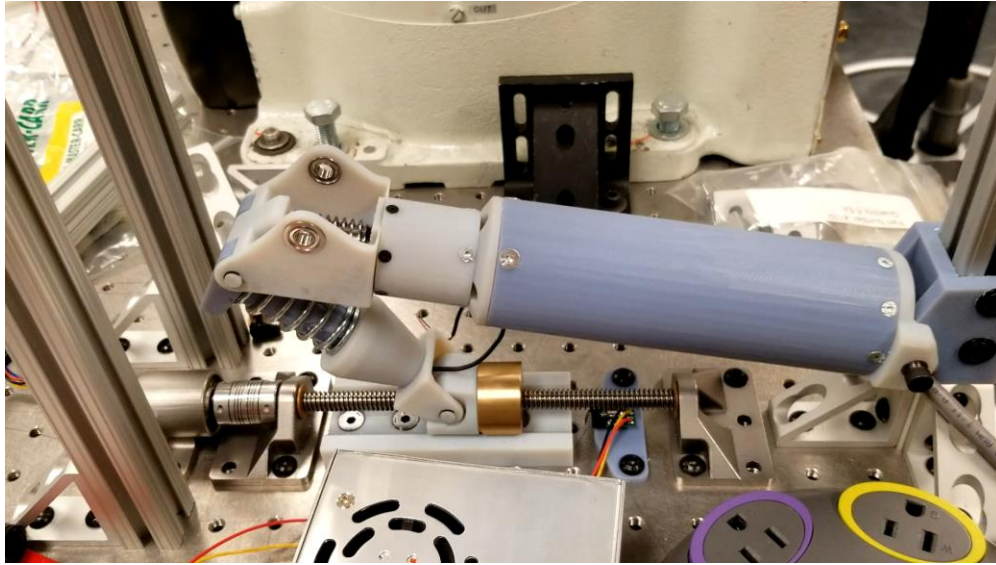
Core Component Development to Scaled Field Adoption



Commercial Deployment

- ▶ Full-scale commercialization will begin in years 4 and 5 after field testing is successfully completed
- ▶ Timing allows for early adopters to be identified, and regulatory requirements satisfied
- ▶ Garney Construction is initial planned installation contractor for the rehabilitation system
- ▶ Licensing to other contractors will be considered in the future
- ▶ Cross-over of developed technologies into water sector and other energy applications will provide additional refinement and commercialization opportunities for PLUTO in year 4 and beyond

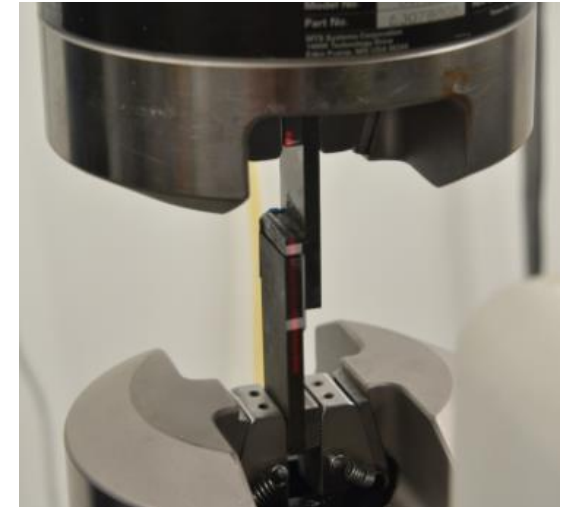
Results: Robot Prototypes



Results: Lining Material Characterization

- Warren 501-02 epoxy initial material properties:

Property		Units	Warren 501-02 Epoxy		Test Methods
			Longitudinal Direction	Circumferential Direction	
Initial Elastic Modulus		ksi	500	500	
Flexural Strength		ksi	14.5	14.5	ASTM D 790
Flexural Modulus		ksi	500	500	ASTM D 790
Flexural Strain		%	4.8	4.8	ASTM D 790
Tensile	Ult. Strength	ksi	7.0	7.0	ASTM D 638
	Ult. Strain	%	7.9	7.9	ASTM D 638
Compressive Ult. Strength		ksi	14.5	14.5	ASTM D 695
Poisson's ratio		N/A	Recommend 0.3	Recommend 0.3	



- ASTM D2990 10,000 hour creep test will begin in January
- Target liner thickness for testing purposes is 200 mils
- Lap Shear Testing:
 - Failures are adhesive (with mild cohesive behavior for ablated samples)
 - Target max load: 1000 lbf
 - Epoxy bonds more strongly and consistently to prepared surfaces

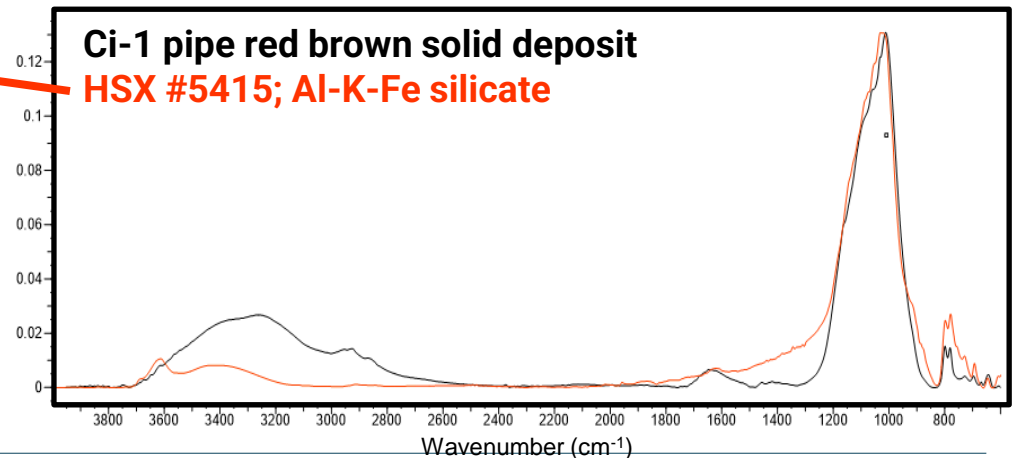
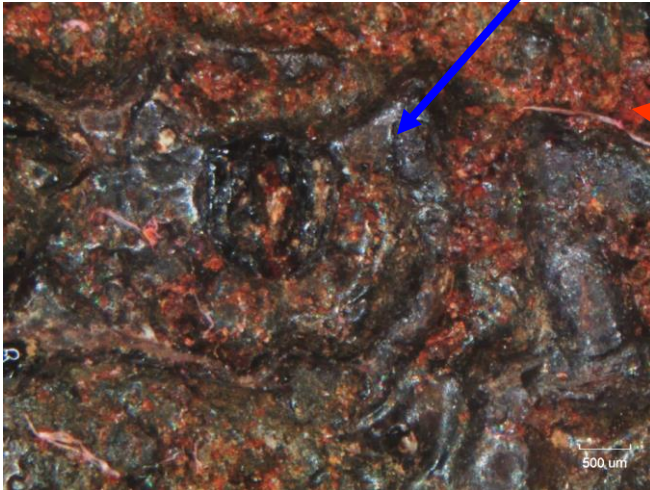
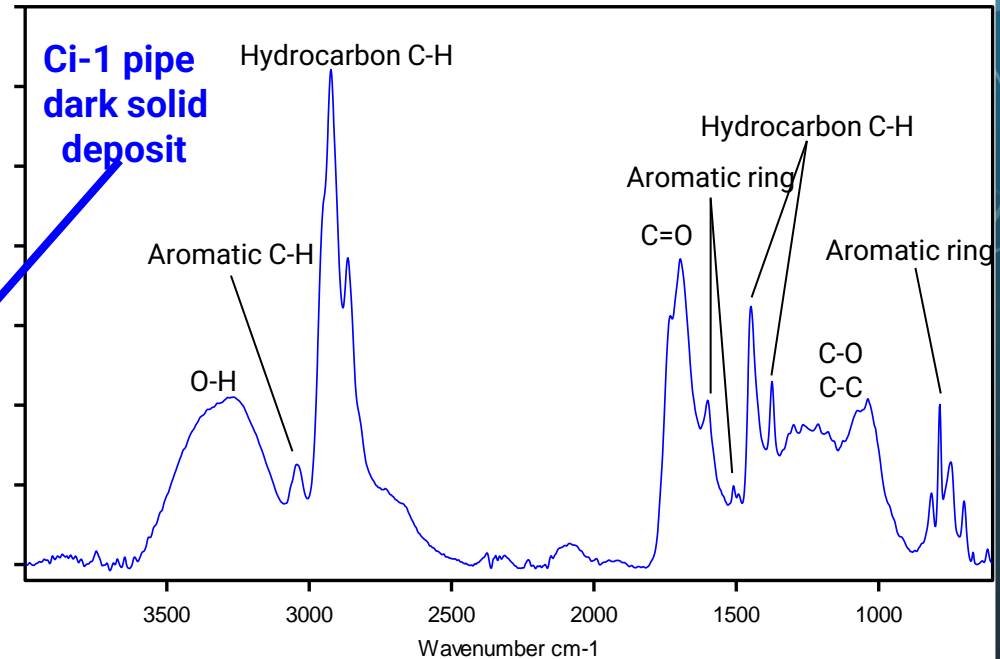


Results: Surface deposits on CI-1 pipe

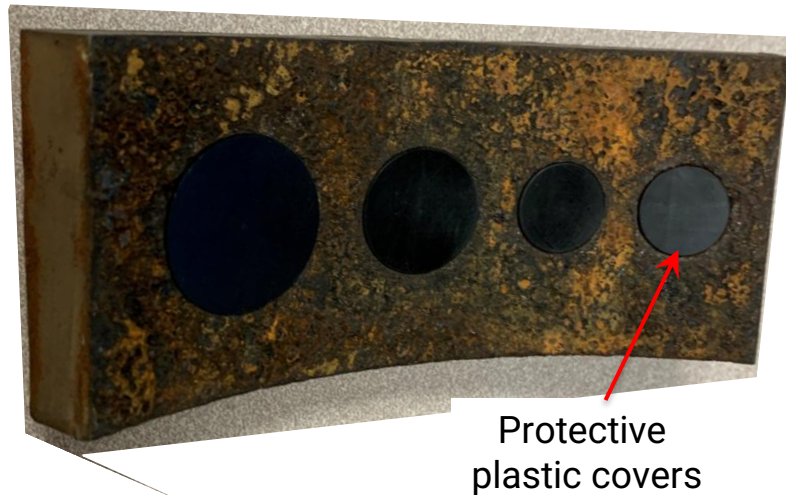
The deposits on the surface of the CI-1 pipe are a mixture of degraded organics and an Al-Fe silicate.

The dark organic deposits have the IR features of hydrocarbons and aromatic rings. These organics can burn if heated in air due to the presence of C-H bonds.

The red brown solid material on the surface matches the IR features of an Al-Fe silicate well.

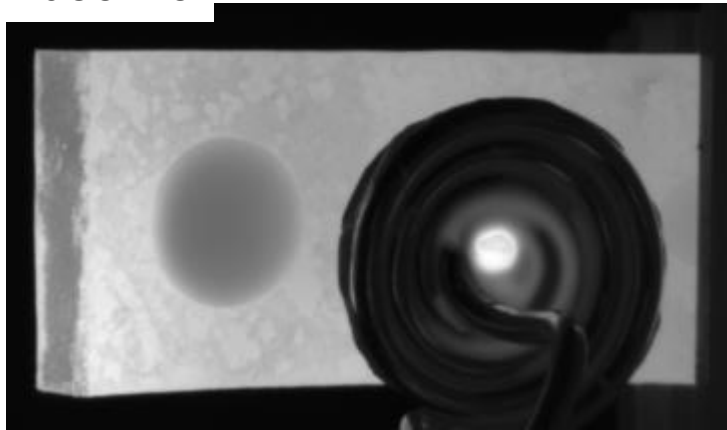


Results: Coupon Inspection Of Overcoated Defects

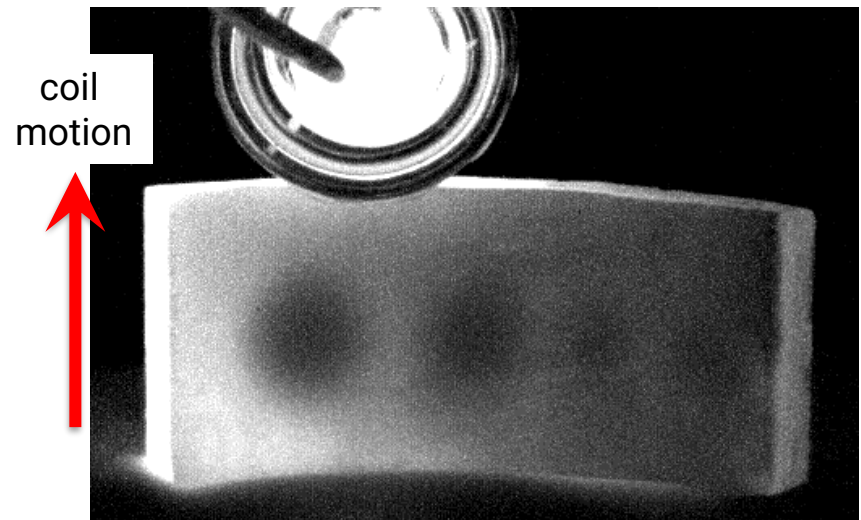


- 4 different diameter blind holes drilled in pipe coupon.
- Holes were “covered” with plastic plugs to keep them from being filled.
- Coupon coated at 200 mils.

Baseline

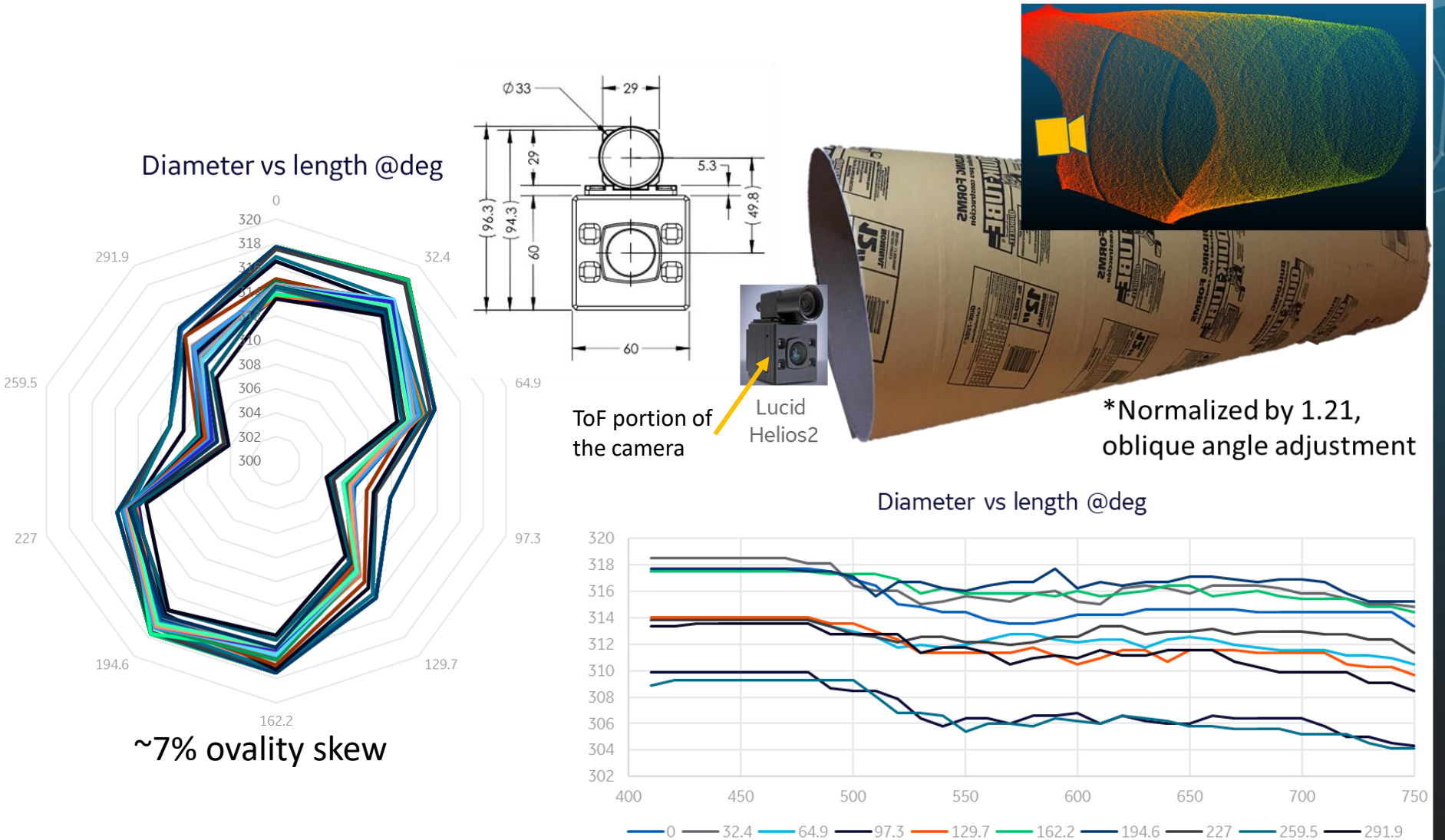


IR image, large hole, uncoated part.



IR image, all holes, coated part.

Results: Pipe Surface Shape Inspection



Risks and Path to Economic Viability

Risk: Regulatory Adoption - A successful technical solution is valueless if it is not trusted for deployment by pipeline owners and regulators

- **Mitigation:** Early and frequent interaction with regulators and pipeline owners through ARPA-E REPAIR program. Cooperatively shape requirements for acceptance.

Risk: Performance - Each system component is unproven in target environment: Access, Materials, Inspection

- **Mitigation:** Design philosophy and risk reduction activities shape solution that is as simple and robust as possible to achieve goals. Test often with regular critical evaluations of system and approach

Potential Partnerships

- ▶ Invite collaboration with teams with complementary technologies:
 - Localization technologies
 - Smart material additives
 - Sensing and mapping capabilities
- ▶ Collaboration and communication with potential early adopters and leading gas industry professionals for input on development starting in year 2 to ensure PLUTO program is on target and will meet their needs

Summary

PipeLine Underground Trenchless Overhaul (PLUTO)



- Project Vision:**
- Improve pipeline longevity and maintenance efficiency by developing a minimally invasive, long-range, structural pipeline rehabilitation system
 - Build a commercial pipe maintenance system for gas transmission and adjacent domains

**Thank
You**

**Any
questions ?**